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Mobility and social inequality: exploring the nexus by the means of sequence analysis and geovisualisation

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Abstract. This paper reports on a study investigating patterns of long- and mid-term mobility over the life course and their potential interrelationships with social inequality. The study focuses on a sample of persons in the Canton of Zurich, Switzerland. We examine whether spatial and temporal characteristics of mobility patterns differ according to indices of social inequality such as gender, educational attainment, or income, and if yes, how. A methodological framework is developed that enables studying the nexus of mobility and social inequality from different perspectives. Sequence analysis is introduced to this research area in order to reveal mobility patterns and to study their temporal characteristics. This approach is complemented with advanced geovisualisation techniques that enable studying the spatial dimensions of the mobility patterns of various social groups. Our results show that different social groups show similar mobility patterns despite their differing social characteristics. Gender inequalities such as women's disadvantage regarding income or educational attainment exist across the mobility patterns. This persistent gender pattern indicates that the mobility patterns do not necessarily differ along the same axes that structure the society and that the relationships between mobility patterns and social inequalities are complex.

Keywords: mobility, social inequality, geovisualisation, sequence analysis

Introduction

Mobility is a central topic for everyday life. But are we all equally mobile if we so desired, do the ways in which we move resemble one another, or do patterns of mobility differ according to our social status? In order to clarify these questions, this study investigates the little explored relationships between mobility and social inequality.

Recently, space has regained attention as an analytical concept in the social sciences. This renewed interest is often referred to as the 'spatial turn' (Döring & Thielmann, 2008). In the course of the spatial turn, also mobility attracts wider interest. Urry's (2000) call for a sociology of mobilities was an important milestone in this process. He described 'a sociology that examines the diverse mobilities of peoples, objects, images, information and wastes' (Urry, 2000: 1). Taking this approach, we can link mobility to central concepts of sociology such as social inequality. Mobility is relevant in an analysis of social inequality because it is an important resource in today's societies, directly linked with economic and cultural access (Ohnmacht, Maksim, & Bergman, 2009). The importance of mobility is further expressed in modern times because of increased levels and forms of mobility, and also because mobilities can change societies, e.g., through space-time compression (Manderscheid, 2009b). Manderscheid considers the ability to be mobile crucial in forming power relations

(Manderscheid, 2009a). She contends that mobility is a force of stratification. Similarly, Kaufmann (2002) sees mobility as a central value in the society and as an indicator of inequality. He suggests conceptualising motility¹ as a form of capital like economic, social, or cultural capital. Thus, it is safe to say that the formation of a ‘mobility paradigm’ reflects mobility as a valuable analytical category by a rising number of scholars (Sheller & Urry, 2006). On the other hand, although many scholars recognise the importance of mobility in today’s societies, a lack of studies on the interrelations between mobility and social inequality still persists (Ohnmacht, Maksim, & Bergman, 2009). ‘Most theories and analyses on social inequality still largely ignore mobilities and space as dimensions and forces within the process of reproducing inequalities’ (Manderscheid, 2009b: 28). By studying patterns of long- and mid-term mobility and by exploring connections with social inequality, this study contributes to filling this gap. The leading research question is whether mobility patterns of various social groups differ in space and time, and if so, how? Building on this question, we further investigated if and how different mobility patterns indicate social inequalities.

Quantitative methods to study social questions

In this study, we suggest a quantitative, technical approach to explore possible connections between mobility and inequality. Geographic Information Science (GIScience) provides a set of powerful methods to study spatial phenomena. For example, feminist geographers demonstrate that Geographic Information Systems (GIS) can be used to address feminist research questions, and are able to produce knowledge that would otherwise be concealed (e.g., Kwan, 1999; McLafferty, 2002; Pavlovskaya, 2002). The feminist engagement with GIS has led to a ‘growing body of work attempting to combine various types of ‘critical’ human geography with methods and techniques reliant on geographic information systems’ (O’Sullivan, 2006). This body of work is often referred to as ‘critical GIS’. Proponents of critical GIS argue that engaging with GIS technologies can enhance ‘social theory in general by representing spatially complex social processes and relationships’ (Pavlovskaya, 2006). Our quantitative approach is based on a similar motivation. .

Selected studies mentioned below exemplify, how links between mobility and social inequality have been studied using GIS methods. For example, Casas (2007) studied social exclusion of disabled people by means of accessibility measures, revealing that disabled people’s mobility and their access to opportunities are restricted. In another study, Schönfelder and Axhausen (2003) modelled and studied activity spaces and related them to social exclusion. They examined whether activity spaces are suitable measures to identify people at risk of social exclusion. When social exclusion is extended to explore the links between gender inequalities and mobility, the home-work link emerges as an important topic. Various studies from the 1980s showed that women’s commute is shorter in terms of distance and time (Hanson & Johnston, 1985; Madden, 1981). A more recent study detected that this is still true today (Crane, 2007). A survey in Switzerland supports Crane’s findings, revealing that the daily travel distance of men is one third longer than that of women (BFS & ARE, 2007). Kwan (1999) used GIS-based visualisation techniques to study out-of-home, non-employment activities in the home-work link. She brought to light that women’s daytime fixity constraints are higher than men’s. Gender differences present an interesting case, however, mobility patterns do not only differ with

¹ As opposed to mobility, which denotes *realised mobility*, motility stands for the *ability to move*. Kaufmann (2002) considers motility (the ability to move) as being more important than mobility regarding social inequality since the amount of realised mobility does not necessarily correspond with a person’s mobility potential.

respect to gender but also depend on other indicators of social inequality, such as income. In Switzerland, e.g., the higher the income, the more a person travels per year (BFS & ARE, 2007). This brief review of the literature demonstrates that there have been attempts to study interrelations between mobility and social inequality. Different kinds of mobilities have been studied and the links between mobility and social inequality are conceptualised in a variety of ways. Most studies focus on social exclusion, as one aspect of social inequality, and on daily mobility, as one element of mobility. This study broadens the perspective by studying patterns of long- and mid-term mobility and by adopting a broader definition of social inequality. The next section delineates the concept of social inequality and specifies the concept of long- and mid-term mobility. Then, the methods and the data are described. Subsequently, the results are presented. The discussion raises the questions whether a quantitative approach is fruitful in this context and what the implications of the results are regarding social theory. To conclude, the findings are summarised.

Social inequality and mobility

Social inequality is a relative and multidimensional concept (Burzan, 2011). Fuchs-Heinritz et al. (2007) define the term social inequality as ‘any kind of difference in the possibilities to participate in society or in the disposal of socially relevant resources’. All differences that constitute social inequalities have to do with power relations (Bradley, 1996). The concept of ‘social inequality’ is relative because the definition of socially relevant resources varies over time and space. It is also multidimensional because there are multiple factors that constitute differences and make up social inequalities. Conceptualising and measuring social inequality is not a straightforward process. The literature suggests a list of indicators such as employment status, income, wealth, education, gender, age, nationality, or ethnicity to capture social inequality (Bradley, 1996; Hradil, 2001). In this study, social inequality is quantified using such indicators.

This study only investigates one aspect of mobility that has not received much attention in the literature so far: long- and mid-term mobility during the life course of individuals, a term introduced by Beige (2008). ‘Long- and mid-term mobility’ is, to a large extent, linked to residential mobility. Residential mobility refers to changes in places of residence (i.e., moves). The distances that are covered can be used to differentiate between different kinds of residential mobility. Franz (1984) distinguishes intra-regional migration and inter-regional migration. Intra-regional migration occurs if some parts of the daily activity pattern stay the same. If the whole activity pattern changes after a move, the migration type is considered inter-regional (Franz, 1984). It is this relationship between residential mobility and the daily activities of a person that the term long- and mid-term mobility² tries to capture. Daily mobility and residential mobility are not independent from each other but interact. For instance, it is possible that an occupational change, which determines the daily mobility of a person, leads to a change of the residential location. By speaking of long- and mid-term mobility, the notion that different kinds of mobility interact is emphasised.

² For the sake of simplicity, hereafter we use the term *mobility* to denote *long- and mid-term mobility*.

Methods

Two methods, sequence analysis and geovisualisation, are combined in order to explore interrelations between mobility and social inequality. This combination allows for studying the temporal and spatial characteristics of the mobility patterns of different social groups. Sequence analysis tries to find mobility patterns in the data. These patterns are subsequently analysed in relation to indicators of social inequality in order to explore possible relationships. The geovisualisation methods take different social groups as a starting point. Different social groups' mobility patterns are visualised and qualitatively compared in order to see relationships.

Data

In this study, we have used a retrospective survey on long- and mid-term mobility during the life course of the surveyed individuals (Beige, 2008). The survey covers 20 years (1985-2005) and was conducted in some municipalities of the Canton of Zurich, Switzerland. By the means of a questionnaire, socio-demographic and socio-economic characteristics of the participants were collected. Longitudinal data on their places of residence, places of work, and education were collected using a multidimensional life course calendar. Since we need geographic locations for our analyses, we have utilised a subsample from the original dataset that has the geographical locations (n=1062).

Operationalisation

In order to study interrelationships between mobility and social inequality, these two phenomena need to be operationalised. Based on the literature, commonly used indicators of social inequality were selected. Table 1 illustrates how these indicators were operationalised and which social groups based on these indicators were examined. The social groups whose mobility patterns were studied comprise the highest and lowest group regarding each indicator (e.g., group with highest income and group with lowest income). To account for the multidimensionality of the concept of social inequality, the interplay between different social groups was also explored. We examined how the variables education, income, and employment differ regarding gender and nationality. For example, we analysed whether the mobility patterns of foreign women differ from those of Swiss women.

Indicator	Operationalisation	Social groups
Income	Monthly personal income	Income < 2000 CHF Income > 14000 CHF
Education	Levels of education	Compulsory education Apprenticeship University degree
Employment	Employment status	Unemployed Employed Home duties
Gender	Male/female	Male Female
Nationality	Nationality	Swiss Non Swiss

Table 1 Indicators of social inequality

We attempted to capture the phenomenon of long- and mid-term mobility by extracting and comparing various patterns of long- and mid-term mobility. The main elements that constitute a long- and mid-term mobility pattern are the places of residence and the respective durations of a stay. The changes in a place of residence and corresponding distances, directions, and the frequency of these changes also play a role (Wagner, 1990). Since different forms of mobility are interconnected, places of work or places of education are also part of a long- and mid-term mobility pattern. The combination of these elements (that is, the frequency of changes, the duration of the respective states, and their spatial configuration) is referred to as long- and mid-term mobility pattern³. Since we use two different analyses approaches, our definition of a *mobility pattern* differs for each approach. In sequence analysis, a sequence or a group of sequences is regarded as a mobility pattern. In geovisualisation based analysis, the shape and the size of the activity space are regarded as a mobility pattern (compare Figure 1).

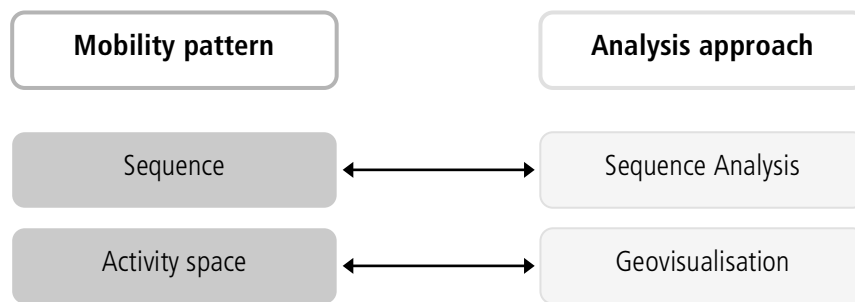


Figure 1 Conceptualising a mobility pattern depending on the analysis approach

Sequence Analysis

Sequence analysis methods were originally developed for the analysis of DNA sequences. A most basic definition of a sequence is ‘an ordered list of elements’ (Abbott 1995: 94). If DNA sequences are studied, amino acids are the elements of a sequence. The order of these elements in a sequence represents the physical order of the amino acids. In the 1990s, sequence analysis methods were transferred to the social sciences by Abbott (1990, 1995). In the social sciences, temporal sequences are often studied. Using the example of the life course, events such as marriage, divorce, or birth of a child can be seen as elements of a sequence. Similarly to DNA sequences or life courses, mobility patterns can be conceptualised as sequences. This approach is particularly promising to analyse temporal aspects of mobility patterns. It requires that time and space are incorporated in the sequence analysis. In order to conceptualise a mobility pattern as a sequence, tracks of people who move through coded spatial entities are treated as sequences. A track can be converted to a sequence by lining up the codes of the spatial entities according to the order of the track through the entities. The spatial entities that are coded in this study are municipalities. The municipalities are divided into different categories according to the typology of municipalities⁴ (Schuler & Joye, n.d.). Each municipality type is assigned a code. Figure 2 depicts the typology of municipalities in the Canton of Zurich. This typology takes various structural variables (e.g., population structure, tourism, wealth, or employment) into account in order to divide the municipalities into groups with similar characteristics. For every person, a sequence is generated which shows in what kinds of municipalities this person lived during the twenty-year period of the survey. Thereby, it is possible to follow up the pattern of a

³ Hereafter we use the term *mobility pattern* to denote the term *long- and mid-term mobility pattern*.

⁴ http://www.bfs.admin.ch/bfs/portal/de/index/regionen/11/geo/raeumliche_typologien/01.html

person's mobility regarding the different municipality types. It becomes visible whether a person stayed in the same kind of municipality for all his or her life or whether the person experienced big changes such as moving from the countryside to the centre. Structural changes in a person's activity space can be revealed using this typology and sequence analysis.

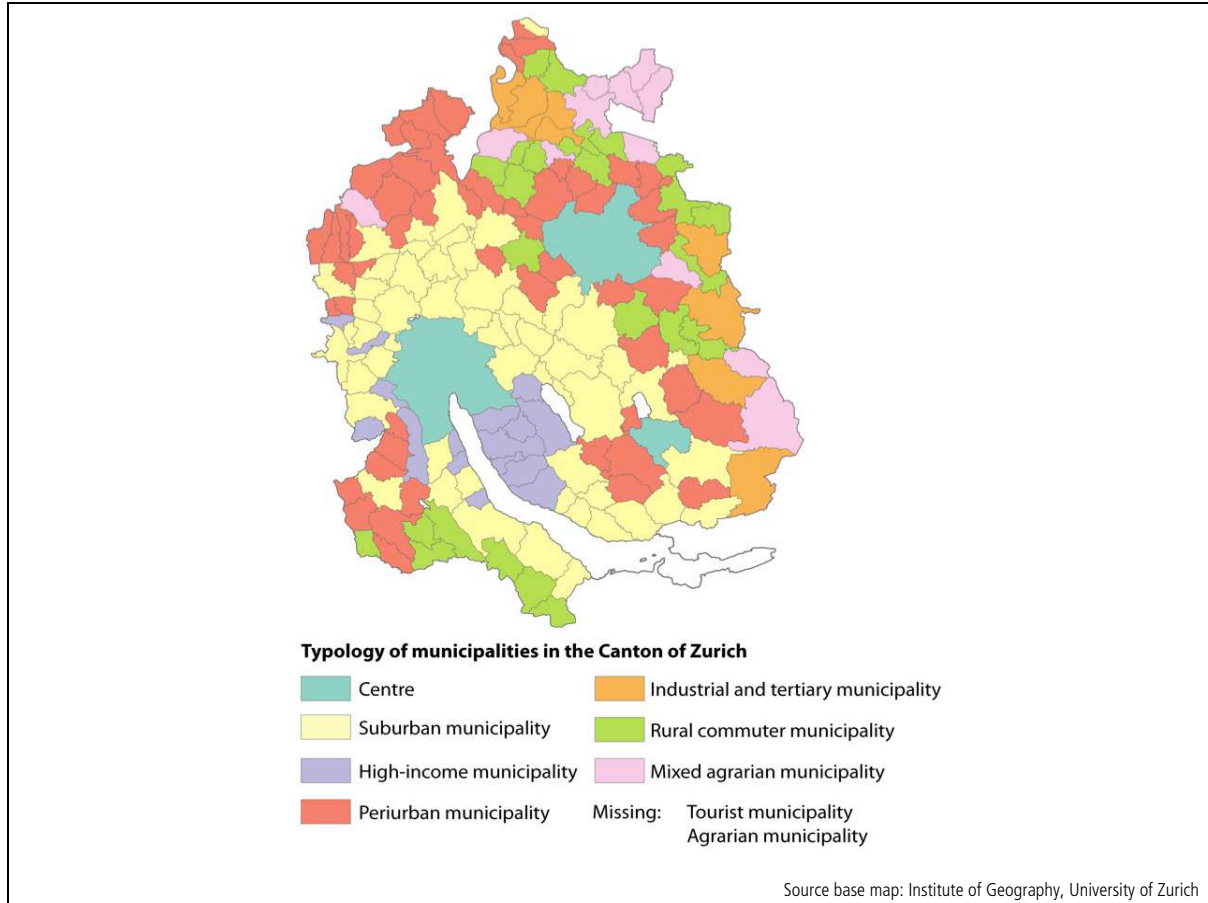


Figure 2 Typology of municipalities in the Canton of Zurich

Figure 3 shows the mobility pattern of one person and illustrates how this pattern is converted to a sequence. Every year during which this person lives in a certain municipality type is represented with a character. Taken together, the characters for every year of the investigation period build the sequence.

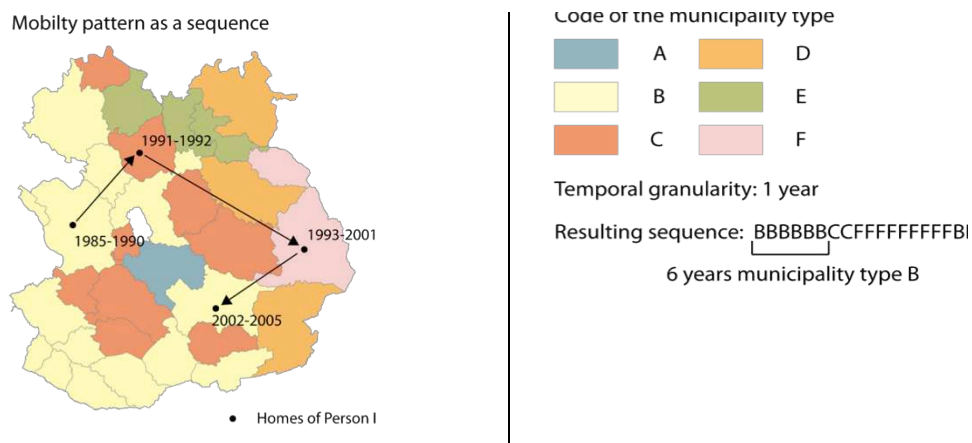


Figure 3 Mobility pattern as a sequence

In this part of the analysis the mobility pattern is only made up of home locations. Other geographical locations like places of work and places of education are not incorporated. In order to identify similar sequences and to study which mobility patterns are predominant, sequence alignment algorithms can be applied. Sequence alignment techniques' main strength is their ability to identify prototypical patterns by means of summarising and categorising sequences (Fabrikant et al., 2008; Çöltekin et al., 2010). In other words, sequence alignment allows for grouping sequences with similar patterns of events. Thus, they help to identify the most frequent mobility patterns that exist in the data. Carrying out a sequence alignment revealed six distinct mobility patterns⁵. The main patterns that have been identified are staying in one municipality type during the whole survey period or moving from one municipality type to another. Table 2 characterises these mobility patterns. The social structure of these mobility patterns was investigated further by means of descriptive statistics in order to study possible relationships with social inequality.

	Mobility pattern
1	foreign country → centre or suburban municipality
2	centre (→ suburban municipality)
3	centre → suburban municipalities, suburban municipality → centre
4	suburban municipalities (with some variation)
5	industrial and tertiary municipality → suburban municipalities
6	periurban municipalities → centre or suburban municipalities

Table 2 Mobility patterns

Geovisualisation

Geovisualisation methods are powerful to render mobility patterns visible, to analyse, and understand them. These methods are particularly useful to study the spatial characteristics of the mobility patterns. Mobility patterns can be analysed by visualising the activity space. The activity space denotes the sum of all places a person (or a group of people) have contact with over the life course (or during a period of their life) on a regular basis. A literature review was conducted in order to identify suitable visualisation techniques (compare Tuggener, 2012). This literature review revealed that kernel density estimation (KDE) and the standard deviational ellipse (SDE) are two promising techniques to visualise activity spaces.

Kernel density estimation generates a density surface which indicates how often a person visits which places. The intensities of the density surface show where the focus of a person's activity space lies. The standard deviational ellipse visualises the activity space as an ellipse. The two main elements that the standard deviational ellipse is able to capture are the activity space's size and its direction. The ellipse shows whether a person's activities take place within a small geographic area or whether the anchor points of a person's life are widespread. The direction of the ellipse shows in which geographical direction the person mainly moved. The activity spaces of the studied social groups were visualised by the means of KDE and the SDE. Figure 4 and Figure 5 show the visualised activity spaces of people with different levels of education as an example.

⁵ For detailed information see Tuggener (2012)

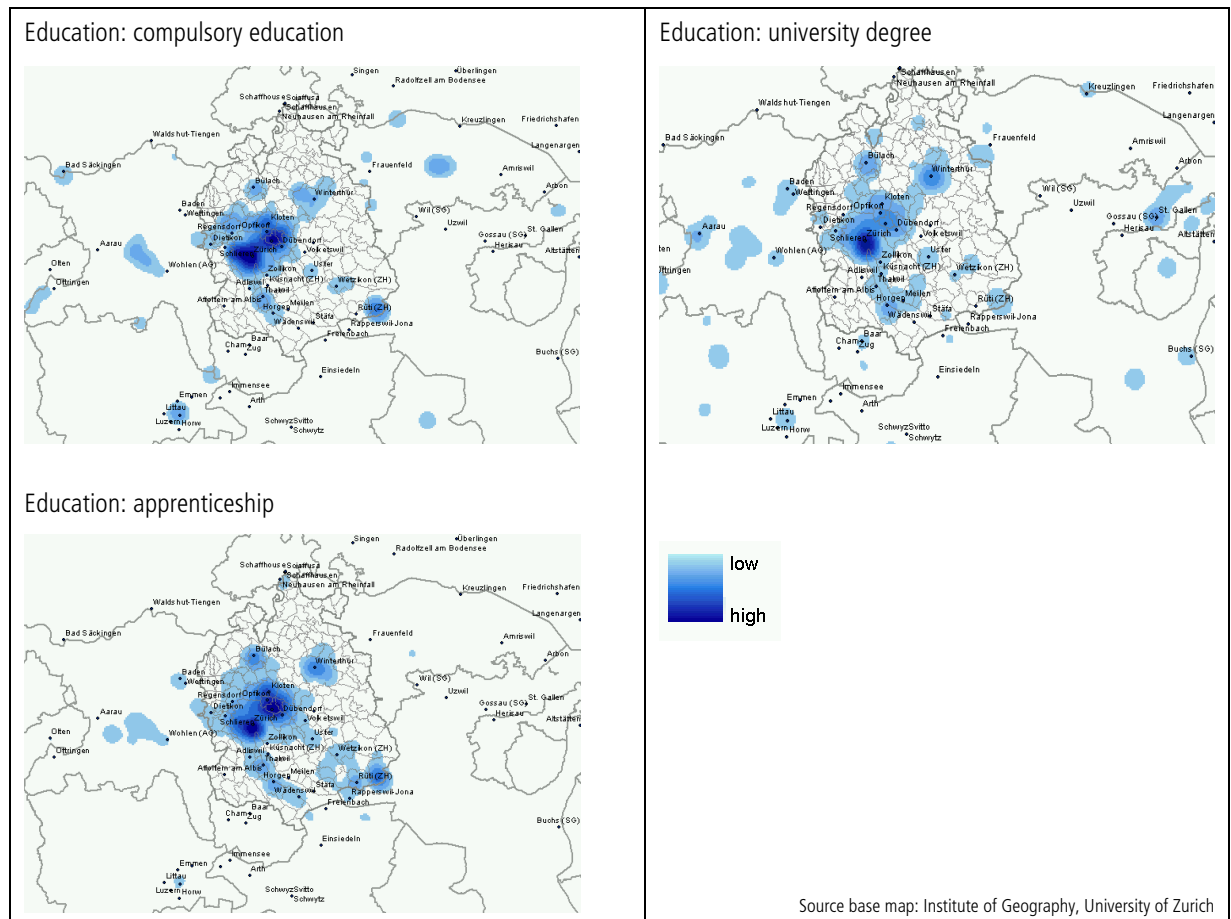


Figure 4 Visualising mobility patterns using kernel density estimation

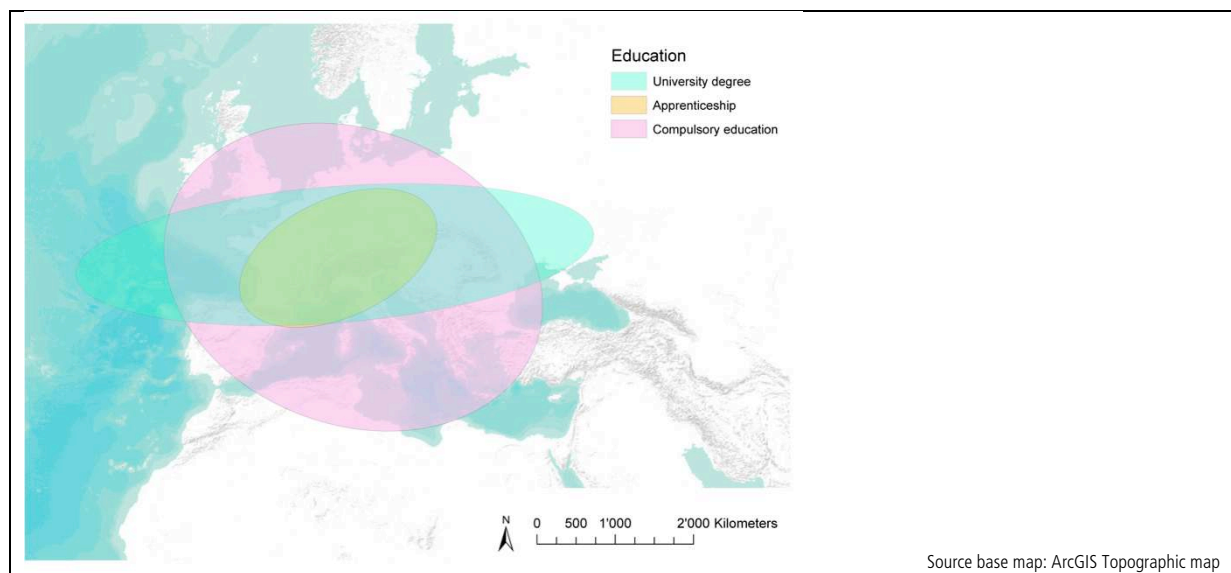


Figure 5 Visualising mobility patterns using the standard deviational ellipse

Analogously, the activity spaces of the other social groups were visualised (see Tuggener, 2012). A visual comparison of the visualised activity spaces revealed differences and similarities of different social group's mobility patterns.

Results

The mobility patterns that *sequence analysis* revealed (see Table 2) are related to indicators of social inequality in order to see if a mobility pattern is related to a certain social group. This analysis gives indications in order to answer the question whether mobility patterns of different social groups differ in space and time, and if so, how. Relationships between the mobility patterns and indicators of social inequality are identified on the basis of a comparison of histograms (see Tuggener, 2012). The social composition of the different mobility patterns is examined regarding the indicators nationality, gender, income, employment situation, and education level. The findings do not build on statistical tests and they are exploratory rather than confirmatory. Studying the social structure of the mobility patterns shows that certain social groups are disadvantaged in several mobility patterns. Differences regarding education level and income between men and women, for instance, draw through all mobility patterns. The degree of disadvantage varies but is not particularly high in one single mobility pattern. There are no clear indications that one mobility pattern is made up of socially disadvantaged people and could be denoted as ‘typical’ mobility pattern for people with a low social status. Moreover, sometimes privileged and disadvantaged social groups are found in the same mobility pattern. An interesting outcome was observed in mobility pattern three (centre-suburban moves). When single indicators are analysed, the people who make up the centre-suburban mobility pattern seem rather privileged (e.g., good education and high incomes). However, if the different indicators are studied together, this impression changes radically. For example, when we study education and nationality together, we can observe that the education level of foreign immigrants appears very low while the citizens of the country (in this case, Swiss nationals) are educated well. However, if we study income in relation to gender, we can see that only men earn well in this mobility pattern regardless of nationality. This result indicates that dimensions of inequality overlap and are interconnected. It is necessary to study the interplay between different indicators. After the sequence analysis, it became apparent that the social structure of the mobility patterns is inhomogeneous. Many inequalities were found across the different mobility patterns and are not linked to one of these patterns. Some mobility patterns comprise people from different social groups and are characterised by more pronounced inequalities than others. Other patterns are rather homogeneous regarding the social structure. However, no social group could be assigned to a certain mobility pattern or to only one pattern, respectively.

The *geovisualisations* of the activity spaces of different social groups show a number of diverse mobility patterns. The example of the visualised activity spaces of people with differing levels of education (see Figure 4 and Figure 5) indicates that the mobility patterns of different social groups may be similar. The standard deviational ellipses reveal that people with high and low education levels share a big activity space. This suggests that people with a university degree and people with a low education level are more mobile than other social groups. However, the results point out that the mobility patterns do not differ systematically according to the indicators of social inequality. We also observed findings contrary to the literature, e.g., that the activity spaces get smaller the higher the income gets. This indicates that the mobility patterns do not differ depending on the indicators of social inequality. It is concluded that the mobility patterns of different social groups do not necessarily differ. If there are differences, they do not systematically depend on the social status.

The question ‘whether mobility patterns of different social groups differ in space and time, and if yes how’ was addressed using sequence analysis and geovisualisation. While interpreting the results, the results of the two methodological approaches cannot be treated as equal. In different ways, the two

methods revealed differing mobility patterns. Applying sequence analysis resulted in six mobility patterns, which differ in their social composition. Sequence analysis indicated that many social inequalities exist within a mobility pattern. Clear differences in the social structure were not found between the mobility patterns. Geovisualisation methods revealed mobility patterns of different social groups. The visualisations indicated that the mobility patterns of various social groups indeed differ. However, they do not necessarily differ depending on the indicators of social inequality. People with a university degree and people with a low education level, for example, are more mobile than other social groups. This example shows that people with a different social status might have similar mobility patterns. There are differences between the mobility patterns of different social groups. However, two social groups with similar social status might have different mobility patterns while two different social groups might have similar mobility patterns. Thus, the findings indicate that no mobility pattern is directly related to a particular social group. We conclude that the mobility patterns do not necessarily differ systematically in space and time regarding indicators of social inequality.

We further studied whether different mobility patterns indicate social inequalities. This question relates to the thought that a certain mobility pattern could always be associated with a certain social group. The mobility patterns of low-income foreigners could, for example, always be similar but distinct to the mobility patterns of another social group. In this case, the existence of social inequalities could be deduced from a certain mobility pattern. In other words, are there systematic differences between the mobility patterns in relation to social inequalities? The answer to the first research question indicates that there are some differences, but no clear relationships have been observed. No obvious link between a mobility pattern and a socially advantaged or disadvantaged group was found. Hence, the question whether different mobility patterns indicate social inequalities cannot be affirmed in this study. Moreover, even if a mobility pattern were related to a certain social group, the causality of this relationship could not be clarified. Also an unambiguous relationship between a mobility pattern and a social group would not automatically signify a cause-effect relationship. Therefore, we conclude that differing mobility patterns do not necessarily indicate social inequalities in the scope of this study.

Discussion

To study the mobility – social inequality nexus, two quantitative methods from GIScience and beyond were applied. What are the advantages of this methodological approach? Using sequence analysis methods and geovisualisation techniques allowed for revealing and mapping the mobility patterns of different social groups in their geographical context. These results were the basis to study possible relationships between the mobility patterns and social inequality. While in-depth qualitative studies require more time, thus samples remain small; we were able to study a large sample (n=1062) in a relatively short time. Using quantitative approaches contributes to providing the context for this geographical and social problem. We demonstrated that quantitative methods do have a strong potential to enhance the understanding of spatial and social inequalities, which is a first step toward removing such inequalities (McLafferty, 1995). However, while using GIS methods, paying attention to reflexivity is essential during the research process (Kwan, 2002). Especially regarding the visualisations that were created in this study, the deduced statements depend on the researcher's background and attitude and should be seen as one possible interpretation. Sometimes the results are ambiguous, which highlights the importance of reflexivity all the more. Using quantitative methods

allows for creating new and different kinds of knowledge, but at the same time imposes special requirements on the researcher.

In our experience, conceptualising and operationalising social inequality was especially challenging. There are various theories that attempt to understand the emergence and the persistence of social inequalities in today's societies. Until the 1970s class and functionalist approaches were predominant (Stamm, Lamprecht, & Nef, 2003). Then, concepts of inequality have been diversified and extended (emergence of milieu and lifestyle concepts). In the course of this diversification, scholars considered more and more criteria to have an influence on social inequality. In this study we took mobility into account as a factor that is related to social inequality. However, after the analysis it remained vague how these two concepts are related. We found certain relationships but overall the study indicates that mobility patterns do not differ along the same axes that structure the society. Regarding social theory, our results clearly demonstrate that social inequality is a multi-faceted concept influenced by many factors. It became apparent that social inequality needs to be understood as multi-dimensional concept with overlapping and mutually connected causes. Besides traditional categories such as gender, race, or nationality, mobility is another interrelated factor. Our results also show that the dimensions of social inequality should not be studied individually but together while exploring possible connections with mobility. This view corresponds well with the concept of intersectionality, which is vividly discussed and applied in contemporary gender studies. Intersectionality is a perspective that focuses on interrelationships between dimensions of social inequality such as gender, ethnicity, nationality, race, or class. These dimensions cannot be conceptualised individually but their intersections should be analysed (Walgenbach, 2012). An intersectional perspective calls for taking the relationships and interdependencies of various axes of inequality into account (Klinger & Knapp, 2005). We encourage adopting an intersectional perspective to study relationships between mobility and social inequality, since our study showed that different results are possible depending on which intersections between dimensions of social inequality are studied. Moreover, our study showed that some individual dimensions are not as central as often assumed. We have found that regarding mobility patterns, gender is not always a decisive factor, nor is income the key-stratifying factor. This also indicates that an intersectional perspective might be valuable. Despite the apparent limitations of our study, it offers intriguing results as the findings challenge some common understanding and earlier results. So, does involvement with GIS really enhance explanations and social theory as Pavlovskaya (2006) states? In our experience, engaging with GIS does open up new possibilities of analysis, but the analyst needs to be aware of the weaknesses the methods and/or the interpretations can introduce. It indeed leads to rethinking some hypotheses, thus may strengthen theory.

Conclusion

We analysed patterns of long- and mid-term mobility and potential relationships with social inequality using geovisualisation techniques and sequence analysis methods. We observed that mobility patterns of social groups differ in space and time. However, studying the mobility patterns of various social groups revealed that sometimes, different social groups, e.g., well educated people and people with low education levels show similar mobility patterns. Gender inequalities such as women's disadvantage regarding income or educational attainment exist across all mobility patterns. This indicates that the mobility patterns do not necessarily differ along the same axes that structure the society and that the relationships between mobility patterns and social inequalities remain ambiguous in the scope of this study, i.e., differing mobility patterns do not necessarily indicate social inequalities.

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